PRINT ISSN 1119-8362
ELECTRONIC ISSN 1119-8362
Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://ww.bioline.org.br/ja
J. Appl. Sci. Environ. Manage.
Vol. 22 (12) 1979–1984 December 2018

Examining the Physicochemical and Microbial Qualities and Mineral Content of Selected Brands of Bottled Water Marketed and Consumed in Asaba, Delta State, Nigeria

OWAMAH, HI

Department of Civil Engineering, Faculty of Engineering, Delta State University, PMB1, Abraka, Oleh Campus, Delta State, Nigeria
Email: owamah.hilary@gmail.com; hiowamah@delsu.edu.ng
Tel: +2348035705814

ABSTRACT: The quality of bottled water sold in Asaba, Delta State, Nigeria, was investigated in this study. Six (6) brands of highly consumed bottled water were randomly selected for evaluation of physicochemical parameters, metallic and nonmetallic inorganic constituents, and microbial properties. The study revealed that physicochemical parameters such as pH, TDS and Chloride ranged between 6.63±0.03-7.54±0.02, 3.3±0.8-88.4±6.1 and 2.48±0.6-39.3±3.6 respectively, while the metal contents were highly variable amongst the bottled water examined. The study also showed from bacteriological analysis, that 5.2 % of tested samples had *Klebsiella sp., Streptococcus faecalis and Pseudomonas aeruginosa.* Values for the physicochemical and non-metal inorganic elements were below the prescribed maximum limits of the World Health Organization (WHO) and Standard Organization of Nigeria (SON). Generally, the bottled waters were found to be microbiologically safe, going by the results of total coliform and heterotrophic plate count and were also not contaminated by heavy metals. A direct comparison of the values obtained with the mineral water categorization system showed low mineral content and hence most suitable for low-sodium diets. The study recommends regular monitoring and analysis of bottled waters sold and consumed in Nigeria for quality assurance.

DOI: https://dx.doi.org/10.4314/jasem.v22i12.19

Dates: Received: 30 November 2018; Revised: 22 December 2018; Accepted 31 December 2018

Keywords: Bottled Water, Water Quality, Public Health, Regular Monitoring, Asaba

Though packaged water was not a common place thing about two decades ago, the situation has changed as many people now depend on it (Rahman *et al.*, 2017; Bong *et al.*, 2009). The promotional works of food industries have discouraged people from drinking municipal (tap) water as everyone has been made to believe that bottled waters are safer. Some consumers also believe that bottled water is medicinal (Semerjian, 2011). In recent times, the quality of bottled water has been brought to question especially during storage (Al-Saleh, *et al.*, 2011). Reports about illegal re-filling from unsanitary water sources have also been documented the in literature (Herath, *et al.*, 2012). The Nigerian bottled water enterprise has remarkably grown in the last ten years due to the general perception that borehole water contains contaminants. As obtainable in most developing nations (Rahman *et al.*, 2017), the source of most bottled water in Nigeria is groundwater; which after abstraction, is treated by filtration, boiling, chlorination etc. Although the bottled water industry in Nigeria has grown rapidly, a few reports have shown that the possibility of microbiological contamination exits (Ngwai *et al.*, 2010). There is also, inadequate scientific information in the literature, about the quality of bottled waters consumed in many Nigeria cities like Asaba. The objective of this study was therefore, to analyze the physicochemical and microbial qualities, and mineral content of selected brands of bottled water marketed and consumed in Asaba, Delta State, Nigeria.

MATERIALS AND METHOD

Sampling: Six (6) common brands of bottled water and four samples of each brand were used for this study. These were obtained from different retail stores within Asaba, for five working days, randomly chosen between the month of April and May, 2017. The sealed bottled waters were refrigerated and analyzed following standard procedures (Clesceri *et al.*, 1998; APHA, 2012).

Testing of water quality: Chemicals of reagent grade were purchased from Onitsha Anambra State, Nigeria for the analysis. For total dissolved solids (TDS), pH and Electrical conductivity (EC) measurements, HI 98129 combined meter (Hanna Instruments) was utilized. Dissolved oxygen (DO) was determined through the use of a DO Meter (Jenway product,

Email: owamah.hilary@gmail.com; hiowamah@delsu.edu.ng; Tel: +2348035705814

Staffordshire, UK). Total hardness (TH), total alkalinity (TA) and chloride were determined using the titrimetric methods (Rahman *et al.*, 2017, APHA, 2012). All the analyses were done in triplicates and mean values computed. Heterotrophs make use of organic compounds for the majority of their carbon needs. With slight modifications, the spread plate method was used to estimate heterotrophic bacteria and total coliforms after slight modifications (Ngwai, 2010, APHA, 2012). Results obtained were reported in cfu mL^{-1}. The analysis of the metals was done using atomic absorption spectrophotometer (Sens AA 3000, GBC, Australia) in line with the procedures in APHA (2012).

Statistical analysis: Experimental data were statistically analyzed with Microsoft Office Excel 2007 package at a significant level of $p < 0.005$ using the analysis of variance (ANOVA). The standard deviations of values obtained were also calculated to indicate the extent of variations.

RESULTS AND DISCUSSION

Water-quality parameters: Table 1 shows values obtained for the physical properties of the different sampled bottled water brands sold and consumed in Asaba. Electrical conductivity distribution ranged from 5.70 to 148.40 (µS/cm) with over half of the samples having EC of less than 100 (µS/cm) (Table 1). Maximum admissible concentration by the WHO is 1000 (µS/cm) for drinking water. Also, no significant difference in EC values ($P<0.05$) was observed among the brands. EC is not only indicative of ions in water; it also increases with the number of ions (Ritter, 2010). In natural waters, total dissolved solids (TDS) mainly come from Mg, Na, K, Ca, chlorides, carbonates, bicarbonates, sulfate etc. (Ritter, 2010) and varies between less than 30 and 6000 mg L^{-1} (WHO/UNEP & GEMS, 1989). The physicochemical behaviour of drinking water could change as a result of intrusion of TDS. It also makes water less palatable (WHO, 2003). Though data linking health effects with the ingestion of TDS are scanty, total mortality had been shown to correlate negatively with the concentration of TDS in drinking water (Rahman *et al.*, 2017). The WHO and SON prescribed limit for TDS is 500 mg L^{-1} (Table 2). Table 1 showed that the TDS in over 90% of the tested bottled water samples were below 90 mg L^{-1}. Total hardness (TH) is one of the important physicochemical water quality parameters. Dissolved metallic ions such as Ca and Mg, from rocks, seepage, and runoff are the major contributors of TH to natural water WHO, 2003). Some other cations like Ba, Fe and Zn also contribute (WHO, 2003). TH in drinking water has not been so linked to adverse health effects in humans (WHO, 2004). When TH in drinking water is above 75 mg L^{-1}, it could bring about negative effects on the balance of mineral compositions of water (WHO, 2003). Furthermore, when it exceeds 500 mg L^{-1}, it makes water aesthetically unacceptable (WHO, 2003). TH of less than 9.87 mg L^{-1} was obtained in all samples and there was no significant difference among values recorded for the different brands ($p < 0.05$). The TH of the selected bottled waters marketed in Asaba was found to be less than the upper regulatory limit of the SON and WHO (Table 2), with average value of below 33 mg L^{-1} in most of the samples.

Table 1: Concentration of physiochemical and microbial parameters of sampled bottled waters

	Brand					
Parameters	A	B	C	D	E	F
Physical parameters						
Electrical conductivity µS cm^{-1}	7.20±1.8	102±11.6	30.60±2.1	28.40±2.4	36.60±3.2	138.60±11.3
Total dissolved solids (mg L^{-1})	3.30±0.8	65±2.8	13±2.1	16.30±0.11	14.20±0.14	88.40±6.1
Total Hardness (mg L^{-1} CaCO3)	2.70±0.11	7.70±0.11	2.60±0.12	2.40±0.15	1.20±0.15	62.30±2.2
Total Alkalinity (mg L^{-1} CaCO3)	2.4±0.3	11.90±0.3	5.10±0.21	15.40±0.27	12.30±0.21	25±1.8
Inorganic non-metal parameters						
pH	7.51±0.02	7.54±0.02	6.63±0.03	6.72±0.05	7.44±0.07	7.32±0.04
Chloride (mg L^{-1})	2.53±0.21	39.30±3.6	2.48±0.6	2.48±0.6	8.82±0.8	28.60±1.2
Microbial Parameter						
HPC (cfu L^{-1})	BD	BD	26±3	BD	BD	22±2.0

**BD=below detection limit'. Parameters such as total coliform with contents below detection limits were not reflected on the table*

Inorganic non-metal constituents: Though pH is closely related with other water quality parameters, it has not been properly and directly linked to human health. The WHO permissible range for pH in drinking water is 6.5-8.5 (WHO, 2007). The bottled water pHs differed significantly at $p < 0.05$ from the lower and upper limits of the WHO. Chlorides are mainly found in natural waters in the forms of sodium, potassium and calcium salts (WHO, 2003). Apart from impairment of metabolism by NaCl and congestive heart failure, toxicity as a result of ingestion of chloride in humans has not been adequately established (Rahman *et al.*, 2017). Though there are only little or no information on the influence of long term high chloride intake, the general belief is that a healthy person can withstand a large dose of chloride intake if fresh water is correspondingly consumed (Rahman, 2017). Chloride concentration of more than 250 mg L^{-1} can lead to a detectable taste in water (WHO, 2003). The range of chloride in the sampled bottled water brands is 2.48±0.6-39.3±3.6. This was found to be significantly lower ($p < 0.05$) than the SON maximum permissible limit (Tables 2).

Table 2 Drinking water quality guidelines

S/N	Parameter	WHO (2006)	SON (2007)
1	pH	6.5–8.5	6.5-8.5
2	Cadmium	0.003	0.003
3	Chloride	-	250
4	Chromium	0.050	0.050
5	Copper	2.00	1.00
6	Iron	0.30	0.30
7	Lead	ND1	0.01
8	Zinc	-	3.00
9	Nickel	0.020	0.02
10	Barium		
111	Nitrate	10	50.0
12	Nitrite	1.0	0.2
13	Sulphate	500	100
14	Total coliform	$0x10^2$	10
15	*E. coli* count	$0x10^2$	-
16	Electrical Conductivity (µS cm^{-1})	1000	1000
17	Total Suspended Solid	-	-
18	Total Solid	-	-
19	Total Dissolved Solid	500	500
20	Salinity (%)	-	-
22	Turbidity	1	5
22	Magnesium	200	0.2
23	Calcium	200	-
24	Sodium	200	200
25	Potassium	30	-
26	Dissolved Oxygen	4	7.5
27	BOD_5	-	6
28	Total Alkalinity (mg L^{-1} CaCO3)	-	-
29	Hardness ((mg L^{-1} CaCO3)	500	150
30	Colour [apparent (Hz)]	15 -apparent (Hz)	15 (TCU)

Notes: Apart from pH and parameters with indicated units, the unit of parameters is mg L^{-1}
Sources: Adapted from Kulinkina et al. (2017) and Sojobi (2016) following minor updating

Microbiological parameters assessment: Assessment of bacterial contamination was done using the HPC and MPN indexing (Aksu & Vural, 2004). From the HPC count in Table 1, more than 90% of the samples were found to be free from bacteria even as the remaining others had HPC count of less than 18 cfu mL^{-1}. Le Chevallier *et al.* (1980) had earlier reported that the HPC count in drinking water ranges from less than 1 to 104 cfu mL^{-1}. It is mainly influenced by pH, temperature, residual chlorine and organic matters. Allen *et al.* (2004) have shown that an increase in HPC count in drinking water may not mean a significant health risk even as no health-related guideline has been given by regulatory agencies. The US EPA has given a maximum permissible limit of 500 cfu mL^{-1} for HPC count in drinking water (Rahman *et al.*, 2017). All the sampled brands had HPC value far less than the maximum stipulated limits of the US EPA (Rahman *et al.*, 2017). When total coliform count (TCC) in drinking water is positive, it suggests that the water had been exposed to the external ecosystem (Dahunsi *et al.* 2014). Mainly, TCC comprises pathogenic enteric bacteria such as *E. coli, Salmonella spp., Shigella spp., Vibrio spp*. (Barua *et al.*, 2016). A positive TCC value signifies that drinking water is unhygienic (Barua *et al.*, 2016). Results from this study showed that all of the bottled water samples either had a zero coliform count or was below detection limit. This is in line with the requirement of the WHO (Table 3).

Metal constituents: Table 3 shows the concentrations of the metals obtained in this study. Metals mainly get to the human system through drinking water. The effect of metal ions on humans could be positive and or negative. While some elements are toxic at trace level, others at low concentrations are essential but toxic in excess (Sojobi, 2016). Calcium (Ca), potassium (K), magnesium (Mg) and sodium (Na) are not only important to humans but are hardly found in drinking water at concentrations that could be harmful. The Ca, K, Mg and Na contents in the bottled waters were significantly ($p < 0.05$) less than the WHO and SON prescribed maximum values. The US-EPA classified Aluminum, Copper, Iron, Manganese, Silver and Zinc as nuisance elements in drinking water as they cause taste, color, and odor (Rahman *et al.*, 2017). Sliver, Iron, Manganese and Zinc in the sampled bottled waters marketed in Asaba, were below detection limits. Though Copper has been reported to cause odor and taste in drinking water and also to cause gastrointestinal illness in humans (WHO, 2004), its concentration in the sampled drinking water was significantly lower ($p < 0.05$) than the health based guideline value of the SON and the WHO. Aluminum values in all sampled brands were significantly ($p < 0.05$) less than the limits proposed by the SON and the WHO (Tables 2). High level of aluminum in drinking water could be attributed to the use of aluminum salts as coagulants during water treatment (Rahman *et al.*, 2017). It has been reported that potentially toxic elements like Arsenic, Barium, Cadmium, Chromium, Nickel and Lead, can cause cardiovascular health problems, kidney disorders, and cancer in humans (Owamah *et al.*, 2013). The bottled water brands surveyed in this study were all found to be are free from these harmful metals (Table 3).

Mineral Water Categorization of Sampled Bottled Water Brands

Often times, bottled waters are labeled 'mineral water', even when they do not necessarily meet with established requirements (Rahman *et al.*, 2017). The classification of water as mineral water involves various physical, chemical, hydrogeological, pharmacological, microbiological parameters specifications etc. (Rahman *et al.*, 2017). Some scales used for the categorization of water as mineral water are the EU and German mineral water classifications. These scales use parameters like extent of mineralization (TDS), level of relevant constituents associated with biochemical functions and percentage salinity (chloride) or hardness (Ca, Mg) (Van der Aa, 2003).

Table 4 shows the categorization of the mineral content of sampled bottled waters using the European Union and German mineral water categorization systems. From Table 4, about 60% of the sampled bottled waters did not meet with the criteria for classification as mineral water. All the samples also contained sodium below 30 mg L^{-1} and could therefore be said to be good for low sodium containing diets' (van der Aa, 2003).

Table 3. Concentration of tested metals in the sampled bottled waters

	Brand					
Parameter	A	B	C	D	E	F
Ba	BD	BD	1.655±0.032	BD	BD	1.655±0.032
Ca	0.0026±0.0001	1.44±0.0003	0.021±0.0001	0.321±0.0002	0.021±0.0001	0.212±0.002
Cd	BD	BD	0.013±0.0083	0.016±0.0044	0.011±0.0072	0.020±0.0062
Cu	3.43±0.24	2.33±0.35	4.51±0.18	5.52±0.20	3.62±0.16	2.43±0.20
K	0.88±0.12	250±10.5	28.9±1.4	22.6±0.9	30.7±1.4	19.9±1.7
Mg	10.5±0.35	300±8	12.7±0.29	8.2±0.11	12.7±0.29	10.8±0.22
Na	0.31±0.001	19.3±0.15	3.1±0.008	5.3±0.009	2.8±0.006	4.8±0.005
Pb	0.9±0.01	1.2±0.01	2.3±0.01	1.8±0.01	2.1±0.03	3.4±0.01

**BD=below detection limit'. Parameters such as Fe, Zn, Cr with contents below detection limits were not reflected on the table*

Table 4: Mineral water content categorization of the sampled bottled waters

Brand	Categorization Criteria					
	mineral content		[b]Salinity		[c]Hardness	
	Value	Category	Value	Category	Value	Category
A	72.6	Low	1.55	Fresh	0.0011	Very Soft
B	16.8	Very Low	2.68	Fresh	0.0362	Very Soft
C	14.8	Very low	3.53	Fresh	0.0032	Very Soft
D	19.2	Very low	3.02	Fresh	0.0231	Very Soft
E	15.3	Very low	2.82	Fresh	0.0048	Very Soft
F	99.6	Low	3.44	Fresh	0.7561	Soft

[a]Very low mineral content: Mineral content (TDS) < 50 mg L-1; Low mineral content: TDS 50-500 mg L^{-1}; Intermediate mineral content: TDS 500-1500 mg L^{-1}; High mineral content: TDS > 1500 mg L^{-1} (Rahman et al., 2017). [b]Fresh: Chloride < 5 mg L^{-1}; Slightly saline: chloride 5-30 mg L^{-1}; Saline: chloride 30-150 mg L^{-1}; More saline: chloride 150-300 mg L-1; Very saline: chloride: 300-1000 mg L^{-1}; Mineral: chloride 1000-10, 000 mg L^{-1} (Rahman et al., 2017).[c]Very soft: Ca +Mg 0-0.5 mEq L^{-1}; Soft: Ca + Mg 0.5-1 mEq L^{-1}; Medium hard: Ca + Mg 1-2 mEq L^{-1}; Hard: Ca + Mg 2-4 mEq L^{-1}; Very hard: Ca + Mg 4-8 mEq L^{-1}; Extremely hard: Ca + Mg > 8 mEq L^{-1} (Rahman et al., 2017).

Findings from this study are similar to findings from previous studies. Adekunle *et al.* (2004) in their study of packaged water consumed in Ibadan, Nigeria, reported that the physicochemical parameters were within the WHO prescribed limits except for pH, which ranged from 6.6-9.7. Later study by Ajayi *et al.* (2008), about the same Ibadan, reported that the physical parameters were within WHO limits for drinking. They further reported that the pH values ranged from 6.6-9.7 and aluminum (0.00 - 0.34 mg/1), fluoride (0.01 - 1.87mg/l) and cyanide from (0.0 - 0.175 mg/l) which were not within permissible limits. Ajayi *et al.* (2008) also reported that bacteriological analysis showed that some of the samples tested had positive coliform counts with the dominant bacteria (*Klebsiella sp., Streptococcus faecalis and Pseudomonas aeruginosa*). The reports of Dada (2008) for Ekiti State and Igbeneghu and Lamikanra (2014) for Ile-Ife, in Osun State, Nigeria were also similar to the findings of Adekunle *et al.* (2004) and Ajayi *et al.* (2008). The present study showed from bacteriological analysis that 5.2 % of the samples tested, had *Klebsiella sp., Streptococcus faecalis and Pseudomonas aeruginosa.* Cases of gastroenteritis, typhoid and cholera as reported by the Nigerian Federal and State Ministries of Health have been on the increase (Ajayi *et al.*, 2008). This shows that more attention needs to be paid to the quality of water consumed by Nigerians.

Conclusion: The quality of bottled water sold and consumed in Asaba, Delta State Nigeria was investigated in this study. Result obtained showed that the physicochemical and non-metal inorganic elements tested were below the prescribed maximum limits of the World Health Organization (WHO) and Standard Organization of Nigeria (SON). The bottled waters were found to be microbiologically safe and not contaminated by heavy metals. The study also revealed that a few of the samples tested had *Klebsiella sp., Streptococcus faecalis and Pseudomonas aeruginosa.* Majority of the samples were found to have low mineral content and hence most suitable for low-sodium diets. Regular monitoring and analysis of bottled waters sold and consumed in Nigeria for quality assurance were therefore recommended.

REFERENCES

Adekunle, LV; Sridhar, MKC; Ajayi, AA; Oluwade, PA; Olawuyi, JF (2004). An Assessment of the health and social economic implications of sachet water in Ibadan Nigeria: a public health challenge. *Afr. J. Biomed. Res.*, 7:5–8.

Ajayi AA.; Sridhar M K C.; Adekunle LV; Oluwande, PA (2008). Quality of Packaged Waters Sold in Ibadan, Nigeria. . *Afr. J. Biomed. Res.*, 11:251–258.

Aksu, H; Vural, A (2004). Evaluation of microbiological risks in drinking water. *Tesisat*, 98, 120-131.

Allen, MJ; Edberg, SC; Reasoner, DJ (2004). Heterotrophic plate count bacteria what is their significance in drinking water? *Intern. J. Food Microbio*. 92(3): 265-274.

Al-Saleh, I; Shinwari, N; Alsabbaheen, A (2011). Phthalates residues in plastic bottled waters. *J. Toxicol. Sci.*, 36(4): 469-478.

APHA (2012). American Public Health Association, AWWA-American Water Works Association, WEF-Water Environment Federation].

Barua, R; Barua, S; Fatema-Tuz-Zohora, M. R; Uddin, M. S; Hasegawa, H; Rahman, IMM (2016). Bacteriological and physicochemical characteristics of Kaptai lake water in terms of public health significance. *Intern. J. Sci. Res. Environ. Sci.*, 4(2): 31-39.

Bong, YS; Ryu, JS; Lee, KS (2009). Characterizing the origins of bottled water on the South Korean market using chemical and isotopic compositions. *Analytica Chimica Acta*, 631(2): 189-195.

Clesceri, LS; Greenberg, AE; Eaton, AD (1998). Standard methods for the examination of water and wastewater (20th ed.). Washington, D.C: APHA-AWWAWEF.

Dada, AC (2009). Sachet water phenomenon in Nigeria: Assessment of the potential health impacts. *Afr. J. Microbiol. Res.*, 3(1): 015-021.

Herath, AT; Abayasekara, C L; Chandrajith, R; Adikaram, NK B (2012). Temporal variation of microbiological and chemical quality of noncarbonated bottled drinking water sold in Sri *Afri. J. Microbiol. Res.*, 3 (1): 015-021.

LeChevallier, MW; Seidler, RJ; Evans, T (1980). Enumeration and characterization of standard plate count bacteria in chlorinated and raw water supplies. *Appl. Environ. Microbiol*, 40(5): 922-30.

Rahman, IMM; Barua, S, Barua, R; Mutsuddi, R; Alamgir, M; Islam, F; Zinnat, A; Begum, H; (2017). Quality assessment of the non-carbonated bottled drinking water marketed in Bangladesh and comparison with tap water. *Food Contr.*73: 1149-1158.

Ngwai1, YB; Sounyo, AA; Fiabema, SM; Agadah, GA; Ibeakuzie, OT (2010). Bacteriological safety of plastic-bagged sachet drinking water sold in Amassoma, Nigeria. *Asian Pacific J. Trop. Med.*, 555-559.

Ritter, JA (2010). Water quality. Denver, CO: American Water Works Association.

Semerjian, L A (2011). Quality assessment of various bottled waters marketed in Lebanon. *Environ. Monit. Asses*. 172(1-4), 275-285.

Van der Aa, M (2003). Classification of mineral water types and comparison with drinking water standards. *Environ. Geol.*, 44(5): 554-563.

WHO (2003). Chloride in drinking-water e Background document for development of WHO guidelines for drinking-water quality (WHO/SDE/WSH/03.04/03). Geneva: World Health Organization.

WHO (2004). Copper in drinking-water e Background document for development of WHO guidelines for drinking-water quality (WHO/SDE/WSH/03.04/88). Geneva: World Health Organization.

WHO (2007). pH in drinking-water- Revised background document for development of WHO guidelines for drinking-water quality (WHO/SDE/WSH/07.01/1). Geneva: World Health Organization.

WHO/UNEP, & GEMS (1989). Global freshwater quality. Oxford: Alden Press. Zoeteman.